TERM TEST ONE: KEY

QUESTION ONE

Proportion and Scaling of a 10-fold taller human

If a human being were 10 times taller than normal, how thick would the legs have to be to provide the same strength as a human of normal height?

The problem has been explored previously in course notes, lecture and assignments. Essentially, compressive strength scales per area, weight scales with volume ($V^{2/3}$ is proportional to A). If the human is 10 times taller, mass will be 10 times more, area must be increased $10^{3/2} = 31$ to maintain the same compressive strength. Other alternatives (compressive $h_{critical}$ and Euler's column) are awkward at best.

[$A^{3/2}$ (8/8); partial credit for effort or creativity]

QUESTION TWO

Physical Meanings

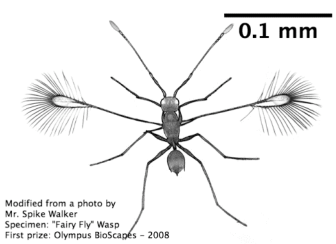
What is a Pascal? Remember that Dr. Lew is not a physicist, and he believes that units are important, in addition to your explanation.

Apparently, pressure (P) is Force (Newtons) per area (m^2) [$P = N \cdot m^{-2}$]. Newtons (N) are $kg \cdot m \cdot s^{-2}$. So, in fundamental units, $P = kg \cdot m^{-1} \cdot s^{-2}$.

[$P = N \cdot m^{-2}$ (7/8); $kg \cdot m^{-1} \cdot s^{-2}$ (1/8); partial credit for effort]

QUESTION THREE

Reynolds number



The fairy fly is reputedly the smallest flying insect. In fact, the feathery appendages can barely be considered wings. How is it that a fairy fly can fly?

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[formula setup (2/8); units (4/8); rational answer (2/8)]

Hints:

A comparative approach may be most useful, considering the physical environment of a fairy fly compared to that of a normal size bird. You can approximate their relative flight velocities as 2000 body lengths per minute. Terminal velocity may also be helpful, and is defined by:

$$V_t = \sqrt{\frac{2mg}{\rho A C_d}}$$

where V_t is the terminal velocity, m is the mass, g the acceleration due to gravity (9.81 m/s^2), ρ the density of air, A the effective area and C_d the drag coefficient (assume it is $24/R_e$).

Reynolds Number $Re = \frac{\rho \cdot v \cdot r}{\eta}$

$0.01\ cm \times 2000 / 60\ sec$
$\times 10^{-2}$ for $m\,s^{-1}$

fairy fly: $\frac{(10^3\ kg\,m^{-3})(0.3\times10^{-2}\ m\,s^{-1})(0.01\times10^{-2}\ m)}{1.813\times10^{-5}\ Pa\cdot s}$

$0.01\ cm$
$\times 10^{-2}$ for m

$\left(\frac{kg}{m\,s}\right)$

$Re = 16$

$C_D = 24/16 = 1.5$

$10\ cm \times 2000 / 60\ sec$
$\times 10^{-2}$ for $m\,s^{-1}$

bird $\frac{(10^3\ kg\,m^{-3})(3.3\ m\,s^{-1})(0.1\ m)}{1.813\times10^{-5}\ Pa\cdot s}$

$10\ cm$

$Re = 1.8\times10^5$

$C_D = 24/1.8\times10^5 = 1.3\times10^{-4}$

Terminal Velocity $\sqrt{\frac{2mg}{\rho A C_D}}$

$(0.01\times10^{-2} m)^3 \cdot (10^3\ kg\,m^{-3})$

fairy fly $\sqrt{\frac{(2)(1\times10^{-9}\ kg)(9.81\ m\,s^{-2})}{(10^3\ kg\,m^{-3})(1\times10^{-8}\ m^2)(1.5)}} = V_t = 0.04\ m\,s^{-1}$

$(0.01\times10^{-2} m)^2$

bird $\sqrt{\frac{(2)(0.001\ kg)(9.81\ m\,s^{-2})}{(10^3\ kg\,m^{-3})(1\times10^{-4}\ m^2)(1.3\times10^{-4})}} = V_t = 39\ m\,s^{-1}$

Basically, the fairy fly barely falls compared to a normal bird.